OXFORD UNIVERSITY SIAM STUDENT CHAPTER CONFERENCE
Abstracts

PLENARY TALKS

Prof Jon Chapman, University of Oxford
Asymptotics beyond all orders: the devil's invention?
"Divergent series are the invention of the devil, and it is shameful to base on them any demonstration whatsoever." — N. H. Abel.

The lecture will introduce the concept of an asymptotic series, showing how useful divergent series can be, despite Abel's reservations. We will then discuss Stokes' phenomenon, whereby the coefficients in the series appear to change discontinuously. We will show how understanding Stokes phenomenon is the key which allows us to determine the qualitative and quantitative behaviour of the solution in many practical problems. Examples will be drawn from the areas of surface waves on fluids, crystal growth, dislocation dynamics, localised pattern formation, and Hele-Shaw flow.

Dr Marek Musiela, University of Oxford
Are quantitative methods important to the financial services industry?

I will start with an overview of the financial services industry to give you a sense of the diversity, complexity and importance of this sector in the global economy. Then I will argue that quantitative methods play transformational role in this industry. To support this claim I will give three examples of quantitative ideas that indeed were transformational for Asset Managers, Hedge Funds and Investment Banks. I will reflect on how the industry evolved over time and how its business models have changed. I will also speculate where this industry is heading and what role quantitative methods play in it today and will play in the future.

INDUSTRIAL TALK by BNP Paribas

Simon Philp, BNP Paribas Fixed Income Research and Strategy
Current problems in FX Options pricing

Foreign Exchange options are used worldwide as both hedging tools and speculation instruments. The job of a market maker such as BNP Paribas is to provide liquidity to the market, whilst controlling their own level of risk through hedging practices. Models based on martingale methods form the core technique to pricing and risk management of exotic FX options. In this presentation we will overview some of the standard methods used to model and price FX options and to present current directions of work. Plus give a flavour of life working as a Quant in the BNP Paribas FX Options team.

ABSTRACTS FOR TALKS

(1) **Lucy Hutchinson**, University of Oxford
A pseudo-multiscale mathematical model of angiogenesis

Angiogenesis is the process by which blood vessels form from existing ones. It occurs in wound healing, fetal development and cancer. We focus on tumour angiogenesis with an emphasis on anti-angiogenic cancer therapy. When a tumour reaches a size larger than around 1mm in diameter, oxygen starved, or hypoxic, regions form. The tumour cells release growth factors that stimulate the growth of new vessels. Preventing the growth of vessels can reduce the delivery of nutrients, thus starving the tumour. Alternatively, controlling the growth of the vessels can increase the delivery of blood to the tumour, and hence increase the delivery of cytotoxic drugs. We have developed a mathematical model to represent several processes involved in angiogenesis on the cellular and sub-cellular scales. Perturbations to the model represent anti-angiogenic drug therapies, and have produced good qualitative agreement with experimental data.

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(2) **Ana Victoria Ponce Bobadilla**, University of Warwick
Modelling calcium waves in different dendritic structures

Calcium ions play an important role in gene transcription, synaptic transmission and plasticity. The objective of this project is to develop an analytical tractable spatiotemporal model of intercellular Ca2+concentration. We take into account two sources for Ca2+: voltage-gated calcium channels (VGCCs) on the dendritic membrane and ryanodine receptors (RyRs) on the surface membrane of the endoplasmic reticulum. This project investigates how the cell geometry and the distribution of VGCCs and RyRs affect the generation and propagation of Ca2+ waves. By imitating the nonlinear behavior of the RyRs and the VGCCs by threshold processes, the model results in a system of coupled partial differential equations which are solved in terms of the appropriate Green function given the domain and the boundary conditions. The model is considered in two simplified dendritic structures where we analyze the critical conditions in the parameter space at which a calcium wave propagates or not and at which a wave may or may not enter the soma. Importantly, this model responds to the scarcity of mathematical models considering internal stores for Ca2+, and it turns to be the first analytically tractable. I will briefly explain the results we have obtain so far, further work and open questions.

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(3) **Matthew Saxton**, University of Oxford
Contact-line dynamics of an evaporating drop

We consider the evaporation of a liquid drop on a smooth solid substrate. To make analytical progress possible, we consider a '1.5-sided' model in which the dynamics of the gas phase are reduced to a diffusion equation for the vapour concentration. In particular, we consider the diffusion-limited thin-film regime of this model and apply a systematic

matched asymptotic analysis in the limit of small slip and large kinetic Peclet number (the ratio between the timescales of diffusive and kinetic effects). We find a rich asymptotic structure with both spatial and temporal boundary layers and are able to derive closed-form solutions for the leading-order evolution of the contact-set radius and macroscopic contact angle. The asymptotic results are validated against numerical simulations and we comment on interesting similarities to, and differences from, experimental observations.

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(4) **Esther S. Daus** , Vienna University of Technology
Hypocoercivity for a linearized multi-species Boltzmann system

In this talk I will present our recent work concerning the evolution of an ideal gas mixture of chemically non-reacting mono-atomic multi-species particles, which can be modelled by a system of linearized Boltzmann equations. For this system we proved exponential convergence towards global equilibrium with explicit rate in the case of hard or Maxwellian potentials with Grad's angular cut-off assumption. This convergence is achieved by an interplay between dissipative collision operator versus conservative transport operator by using the hypocoercivity method of Mouhot and Neumann. Starting from the homogeneous linearized Boltzmann equation for a single-species gas I will show step-by-step how spectral gap estimates and hypocoercivity techniques can be used to prove exponential decay.Finally I will discuss the essential problems in the case of multi-species mixtures and how to overcome these problems.

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(5) **Dr Almut Eisentraeger**, University of Oxford
How meshes and chains improve magnetic separation

High gradient magnetic separation is an efficient way of removing magnetic and paramagnetic particles, such as heavy metals, from waste water. As the suspension flows through a mesh of magnetized steel wool, high magnetic gradients around the wires attract and capture the particles. We model such a system by considering a single point dipole travelling through a periodic array of magnetized cylinders. We show that there is a critical Mason number (dimensionless flow velocity) below which the particle is captured independent of its initial position. After discussing these effects, we consider how several particles interact with each other magnetically and hydrodynamically, and how aggregation of the particles to chains further speeds up separation.

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(6) **Arnold Mathijssen**, University of Oxford
Tracer trajectories and displacement due to a micro-swimmer near a surface

We study tracer particle transport due to flows created by a self-propelled micro-swimmer, such as a swimming bacterium, alga or a microscopic artificial swimmer. Recent theoretical work has shown that as a swimmer moves in the fluid bulk along an infinite straight path tracer particles far from its path perform closed loops, whereas those close to the swimmer are entrained by its motion. However in biologically and technologically important cases tracer transport is significantly altered for swimmers that move in a run-and-tumble fashion with a finite persistence length, or/and in the presence of a free surface or

a solid boundary. Here we present a systematic analytical and numerical study exploring the resultant regimes and their crossovers. Our focus is on describing qualitative features of the tracer particle transport and developing quantitative tools for its analysis. Our work is a step towards understanding the ecological effects of flows created by swimming organisms, such as enhanced fluid mixing and biofilm formation.

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(7) **Nanxin Wei**, Imperial College London
Critical behavior of aging interdependency networks

In this joint work we studied an aging process on interdependency networks, i.e. each node of the networks follows simple dynamics of death/recovery (inactivate/reactivate) on condition that its dependency relation stands. Previous study showed that for zero recovery rate, the aging properties of such networks converge as the size of the networks grows. We discovered that when the recovery/death ratio goes up to a threshold value, the networks exhibit divergent aging properties similar to the critical behavior observed in equilibrium physical systems. More interestingly, above the threshold ratio, the cascading events (node death caused by breaking dependency relation) in the network seem to fit a finite scaling ansatz, indicating the system may be characterized by self-organized criticality in this parameter regime, with rich phenomenology to further explore. Implications can be drawn to biological, financial or electrical power networks.

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(8) **Linus Schumacher**, University of Oxford
Exploring the principles of collective cell migration and self-organisation

We explore the role of collective cell migration and self-organisation in the development of the embryo through mathematical modelling and simulation, as well as data analysis and comparison with theory. Two specific applications are (1) multicellular streaming migration in chick cranial neural crest and (2) mouse skin cell self-organisation.

Neural crest cell migration is an important feature of vertebrate development and an emerging system for metastatic invasion. We study how leading and trailing subpopulations of cells are determined in the chick cranial neural crest to maintain robust directed migration. These cell subtypes are thought to be induced by microenvironmental cues and to transmit directional information between each other. We extend a hybrid agent-based computational model to investigate the effect of different cell-subpopulations and their plasticity on migration outcome, in close integration with in vivo experiments.

We then turn to a different biological system to test the capacity of simple cell interactions to produce self-organisation of tissue structures. We characterise the clustering of mouse epidermal cells in a skin reconstitution assay, using a more data-driven approach and scaling theory rather than simulations, and find it to be consistent with the dynamics of randomly moving, irreversibly aggregating particles.

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(9) **Dr Omri Ross**, Technical University of Denmark
Feature selection for portfolio optimization

Most portfolio selection rules based on the sample mean and covariance matrix perform poorly out-of-sample. Moreover, there is a growing body of evidence that such optimization rules are not able to beat simple rules of thumb, such as 1/N. Parameter uncertainty has been identified as one major reason for these findings. A strand of literature addresses this problem by improving the parameter estimation and/or by relying on more robust portfolio selection methods. Independent of the chosen portfolio selection rule, we propose to use feature selection first in order to reduce the asset menu. While most of the diversification benefits are preserved, the parameter estimation problem is alleviated. We conduct out-of-sample back tests to show that in most cases different well-established portfolio selection rules applied on the reduced asset universe are able to improve alpha relative to different prominent factor models.

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(10) **Chaman Kumar**, University of Edinburgh
On tamed Milstein scheme of SDEs driven by Levy noise

Motivated by the work of Sabanis [3] and Dareiotis [1], in joint work with Sabanis [2], we propose an explicit tamed Milstein scheme to numerically approximate stochastic differential equations driven by Levy noise with super-linear drift coecient. New techniques have been developed to overcome the challenges arising due to jumps. The rate of convergence is shown to be close to one, which is consistent with the convergence rate of the classical Milstein scheme.

[1] Dareiotis, K., Kumar, C. and Sabanis, S. 2014. On Tamed Euler Approximations of SDEs Driven by Levy Noise with Applications to Delay Equations. arXiv:1403.0498v2.
[2] C. Kumar and S. Sabanis 2014. On Tamed Milstein Scheme of SDEs Driven by Levy Noise. arXiv:1407.5347.
[3] Sabanis, S. 2013. A note on tamed Euler approximations. Electronic Communications in Probability, 18:1-10.

ABSTRACTS FOR POSTERS

(1) **Ferdinando Randisi**, University of Oxford
A salt dependent, coarse-grained, structural model of DNA

Structural modelling has proven crucial in understanding the behaviour of DNA in both biology and in DNA-nanotechnology. While most DNA nanotechnology happens in water solutions at high salt concentration, where electrostatic effects are neglectable, biology and some DNA nanotechnology involve a lower salt concentration, where electrostatic forces need to be taken into account. Here I present a model that can represent DNA at any monovalent salt concentration between 0.1 M and 1.0M. The model is a modified version of oxDNA, a model that has been able to reproduce several structural and dynamical properties of many DNA structures (DNA origamis, plectonemes, cruciforms, burnt-bridges motors, etc.). The model has been obtained by adding a Debye-Huckel electrostatic repulsion interaction to the backbone sites of oxDNA. The interaction has been parametrised in order to reproduce the melting temperatures of DNA duplexes at different salt concentrations. The model is able to correctly reproduce the persistence length of large DNA duplexes in different salt concentrations, and will be used to study how salt concentration influences the properties of DNA.

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(2) **Rachel Bennett**, University of Oxford
A Steering Mechanism for Phototaxis in Chlamydomonas

Chlamydomonas is an alga that swims at low Reynolds number and steers towards or away from a light source. It has a single eyespot near its equator and as the cell rotates during forward motion the light signal received by the eyespot varies. We use a simple mechanical model of Chlamydomonas that couples the flagellar beat pattern to the light intensity at the eyespot to demonstrate a mechanism for phototactic steering that is consistent with observations. The direction of phototaxis is controlled by a parameter in our model and the steering mechanism is robust to noise. Our model shows switching between directed phototaxis when the light is on and run-and-tumble behaviour in the dark.

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(3) **Mariia Koroliuk**, University of Warwick
A Phylogenetic Comparative Method

In this project we will solve the problem of reconstructing trait values from incomplete data samples, while phylogenetic three is not reconstructed. The method is tested on simulations and is applied to a data sample of a family named Caninae and it's three subfamilies. We used 2 approaches: maximum likelihood and Bayesian to find the best fitted value and intervals to three models, namely Brownian motion, Brownian motion with trend and Ornstein-Uhlenbeck . We used likelihood ratio test and Akaike information criteria to find the best model.

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(4) **Elena Camacho Aguilar**, University of Warwick
Geometry, epistasis and development.

I am investigating a new approach to developmental patterning based on a paper of F. Corson and E.D. Siggia [1]. They studied vulval development in C. Elegans which is a very well studied system with extensive quantitative experimental data. In order to extract the essential features of the biological system they construct a very abstract and simple model and then fit this to a very large amount of data. In my poster I discuss an improved approach to the fitting of the data. We make use of the Linear Noise Approximation method, developed by N.G. Van Kampen and T.G. Kurtz to deal with stochastic differential equations. In my thesis work I am developing an amended version of Corson-Siggia approach that uses singularity theory.

[1] Corson, F., & Siggia, E. D. (2012). Geometry, epistasis, and developmental patterning PNAS doi:10.1073/pnas.1201505109/-/DCSupplemental

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(5) **Jiarui Cao**, University of Warwick
Dynamics of condensation in the totally asymmetric inclusion process

The inclusion process is an interacting particle system where particles perform independent random walks with a diffusion rate d in addition to an 'inclusion' effect. The rates for inclusion jumps are proportional to the product of the occupation numbers on departure and target site. In the limit of vanishing diffusion rate a condensation phenomenon occurs where all particles concentrate on a single site in a typical stationary configuration. We focus on the totally asymmetric one-dimensional caseith nearest neighbour jumps. Our aim is to analyse the dynamics of the condensate's emergence in the thermodynamic limit with fixed average particle density. The whole time evolution can be divided into four regimes, nucleation, coarsening, saturation and stationarity. We describe each of them heuristically, with a particular emphasis on the power law behaviour in the coarsening regime.

This is a joint work with Paul Chleboun and Stefan Grosskinsky. J.Stat.Phys. 155(3), 523-543(2014)

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(6) **Antonietta Ambuehl**, University of Oxford
Model reduction with guaranteed accuracy using a posteriori error analysis

The underlying mechanisms of biological processes often give rise to systems of differential equations, with a large number of equations and (usually a lot of) parameters.
Our (two-fold) goal...
1. On the one hand we seek to understand the model, what its key features are, which components of the solution influence others, and which are important for an outcome of interest.
2. At the same time we would like to have a measure for the accuracy of the computed solution, be that the solution of the original model or be that the solution of an alternative

model that captures the essence of the original.
...and how to achieve it
1. Via model reduction, meaning a simplification of the original system of equations, be that a reduction of the number of equations in the system, or a simplification of the individual equations.
2. A measure of the accuracy of the computed or approximate solution on the other hand, is given by error analysis. We are interested in an a posteriori error since we seek a measure for the accuracy of an approximate solution in relation to the true solution.
We will present the mathematical framework together with mesh refinement and model reduction algorithms. The ultimate goal is to obtain a reduced model for a user-defined quantity of interest, that yields similar results as asymptotic analysis. This should ideally be an automatic process and applicable to a general class of ODEs.

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(7) **Markov Pavel**, Heriot-Watt University
Upscaling of theoretical models and experimental data for multiphase flow in porous media

The presence of various scales in natural reservoirs demands from us using of different approaches and mathematical tools for modelling. Two transitions from different scales are shown in this presentation:

- The transition from a continuous space of differential equations to a discrete space of difference models with help of Lie groups theory and further transition between different meshes with the preservation of symmetries.
- The transition from pore and core scales to the scale of a grid with using of porosimetry data analysis and calculations of relative permeability on the basis of pore network modelling.

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(8) **Andrew Gibbs**, University of Reading
Hybrid numerical asymptotic approximation for multiple scattering problems

We propose a hybrid numerical-asymptotic boundary element method well suited to a particular class of multiple scattering problems. Standard numerical schemes for scattering problems have a computational cost that grows at least in direct proportion to the frequency of the incident wave. For many problems of scattering by single obstacles, it has been shown that a careful choice of approximation space, utilising knowledge of high frequency asymptotics, can lead to numerical schemes whose computational cost is independent of frequency. Here, we extend these ideas to multiple scattering configurations, focusing in particular on the case where one obstacle is much larger than the others.

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(9) **Nanxin Wei**, Imperial College London
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recovery rate, the aging properties of such networks converge as the size of the networks grows. We discovered that when the recovery/death ratio goes up to a threshold value, the networks exhibit divergent aging properties similar to the critical behavior observed in equilibrium physical systems. More interestingly, above the threshold ratio, the cascading events (node death caused by breaking dependency relation) in the network seem to fit a finite scaling ansatz, indicating the system may be characterized by self-organized criticality in this parameter regime, with rich phenomenology to further explore. Implications can be drawn to biological, financial or electrical power networks.

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(10) **Nazar Faizan**, University of Warwick
Locality of the TFW equations

In this talk I will discuss the existence and uniqueness of a coupled system of partial differential equations that arises from minimising the Thomas-Fermi-von Weizs acker energy functional for general infinite nuclear arrangements. This gives rise to stability estimates, which give pointwise control of the electron density in terms of a local nuclear defect. We then discuss the applications of this result, including the neutrality of local defects in TFW theory and the lattice relaxation problem.?
